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(54) Abstract Title
Method and device for controlling a clutch

(57) A method for detecting and processing faults as part of incremental measuring of the position and/or speed of an element which can be a clutch actuator of a motor vehicle. Two sensors 26 are arranged off-set along the path of movement of the element. In the event of movement of the element, the sensors produce phase-offset impulse signal sequences which are evaluated through an evaluation circuit 14 to detect the position and/or speed. The two impulse signal sequences are subjected to a correlation check and/or a plausibility check with regard to the evaluation result.

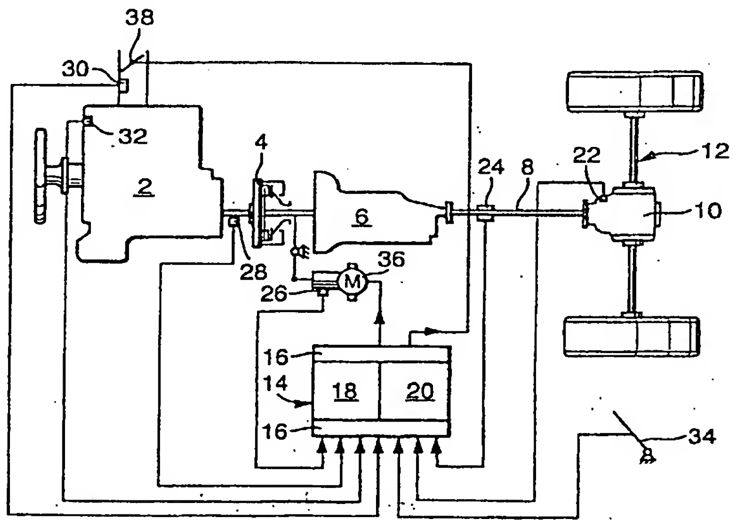

Fig. 1

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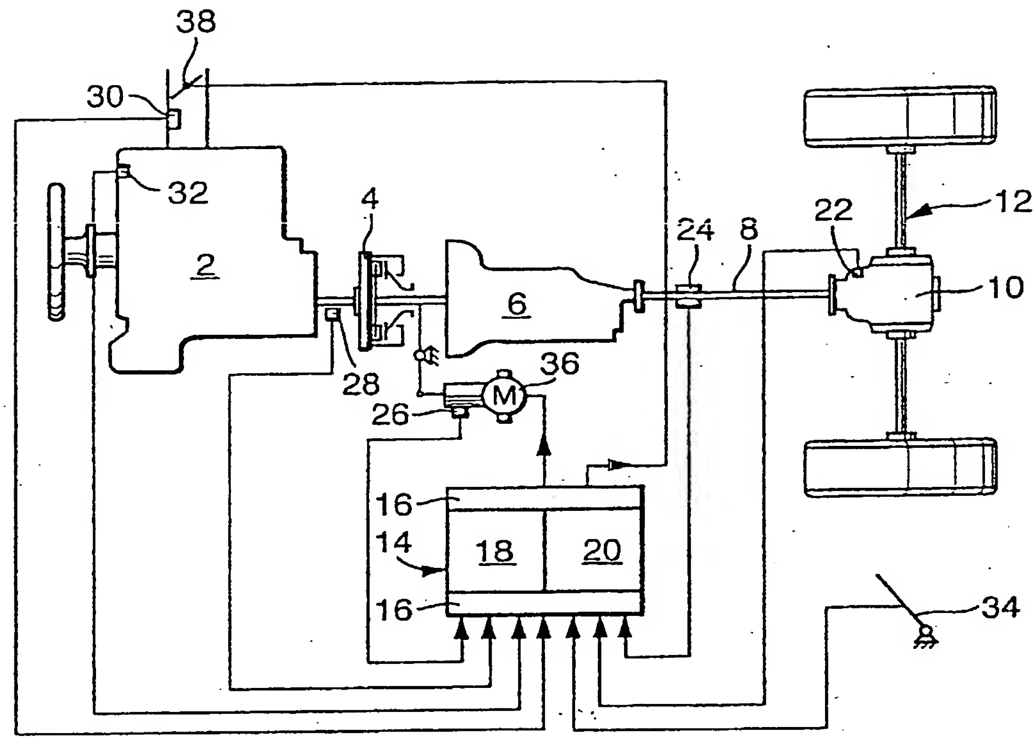

38
30
32
2
4
6
24
8
22
12
10
36
28
26
M
16
14
18
20
16
34

Fig. 1

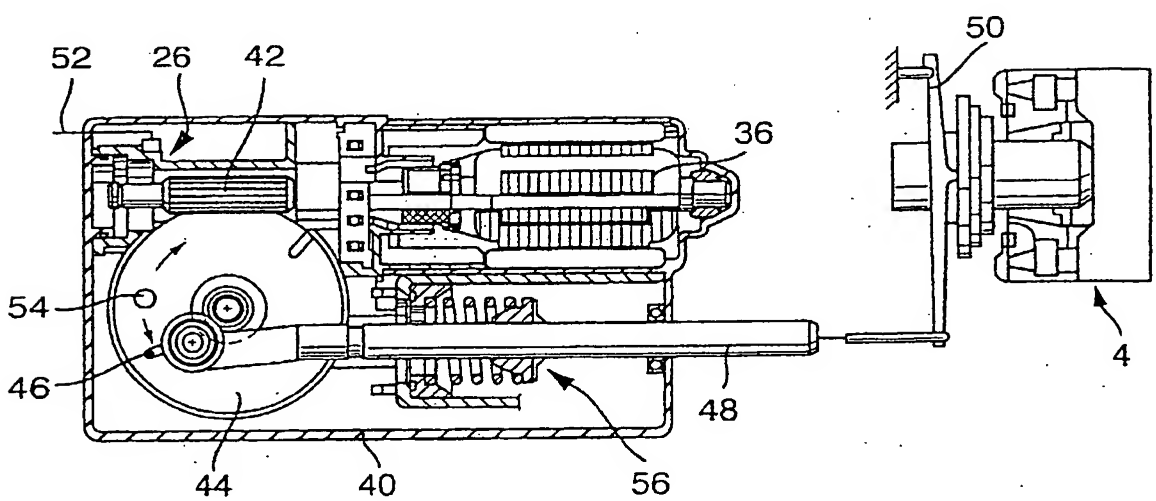

52
26
42
36
50
54
46
48
4
44
40
56

Fig. 2

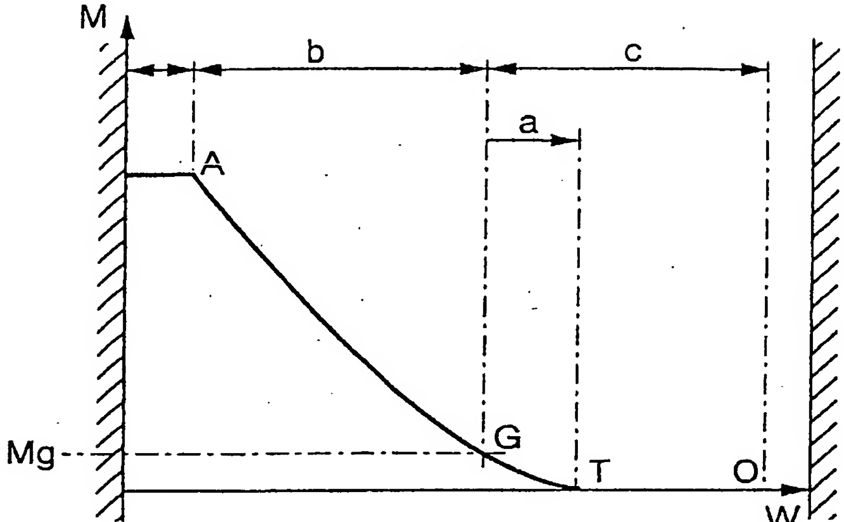


Fig. 3

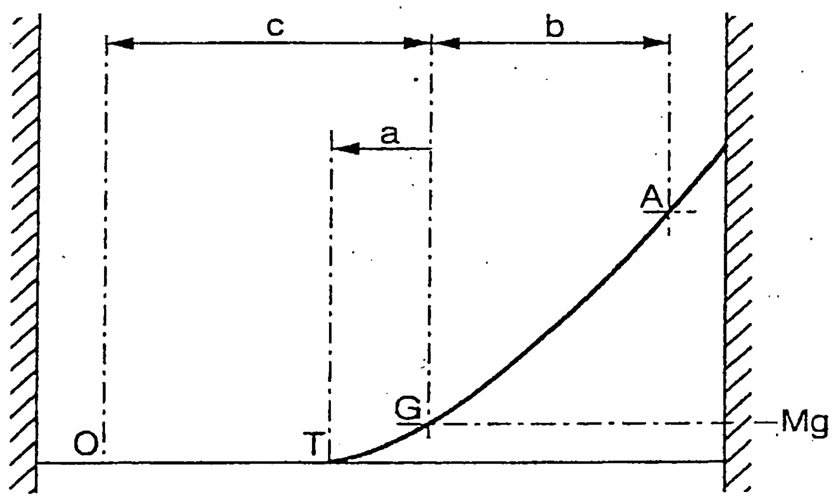


Fig. 4

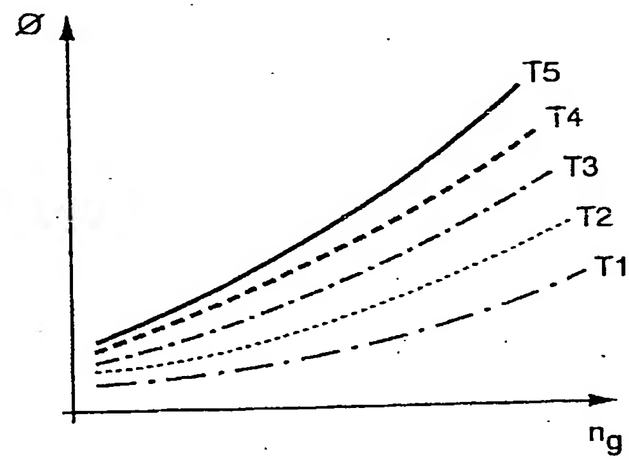

Ø
T5
T4
T3
T2
T1
n_g

Fig. 5

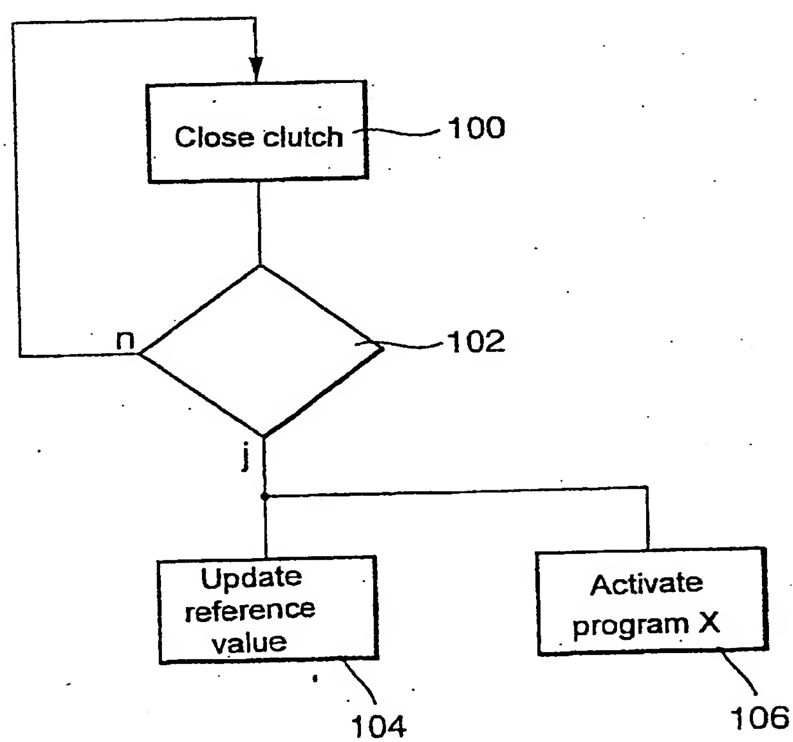

Close clutch
100
n
102
j
Update reference value
Activate program X
104
106

Fig. 6

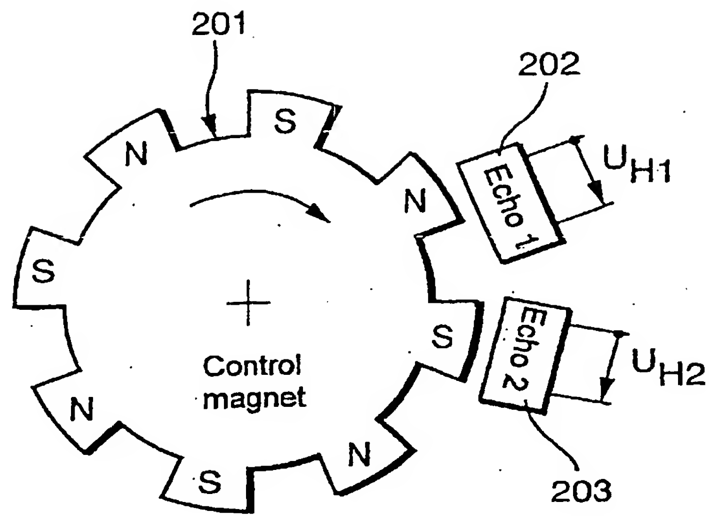

201
202
S
N
N
Echo 1
U_{H1}
S
S
Echo 2
U_{H2}
Control magnet
N
N
S
203

Fig. 7

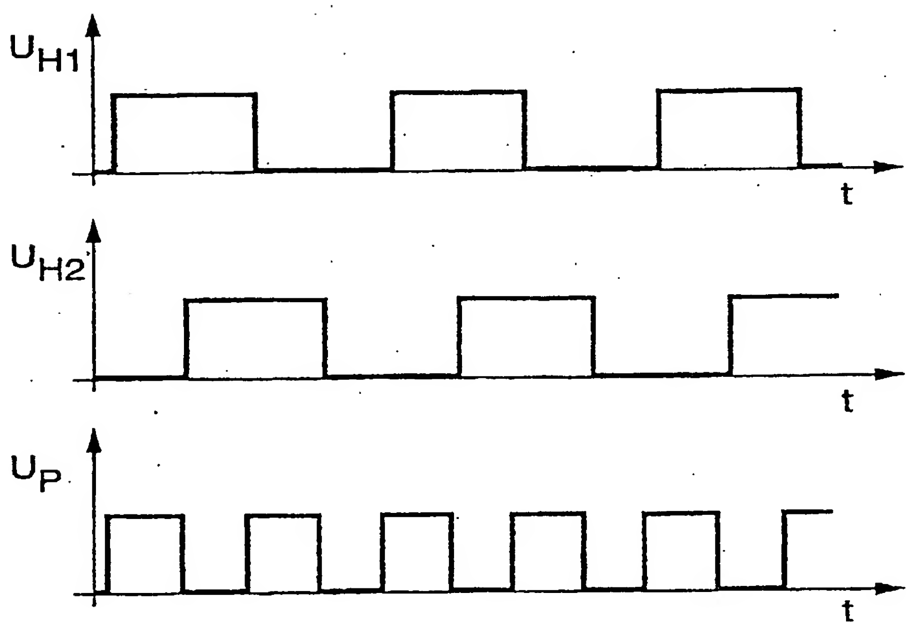
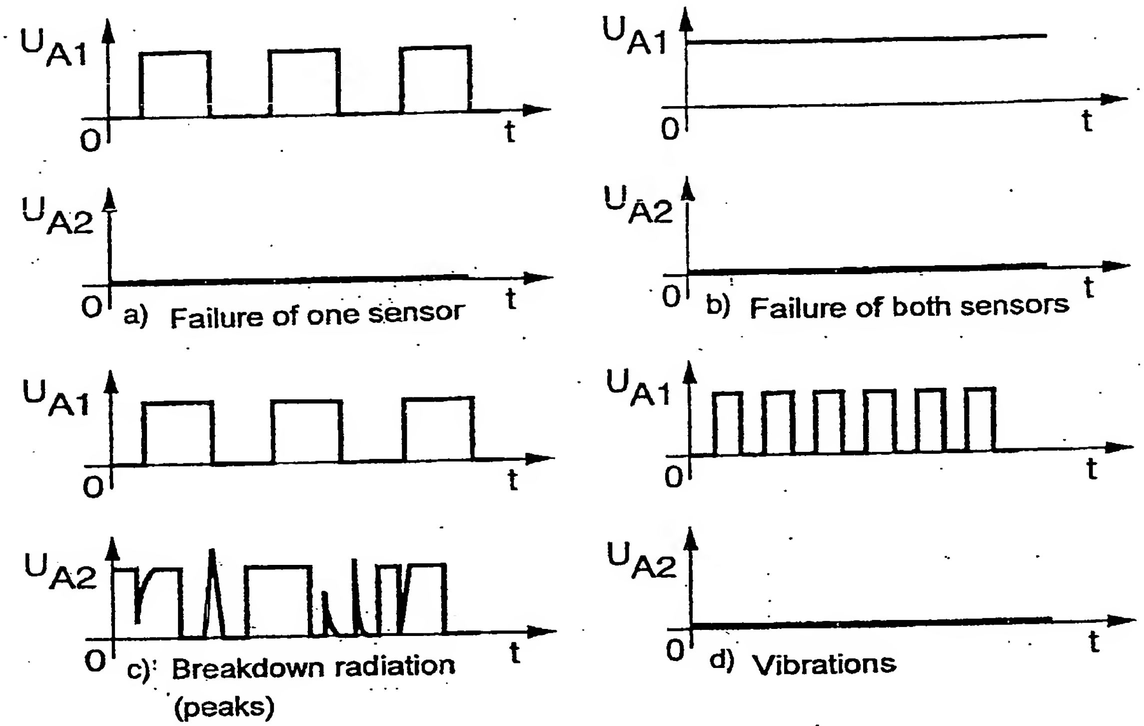
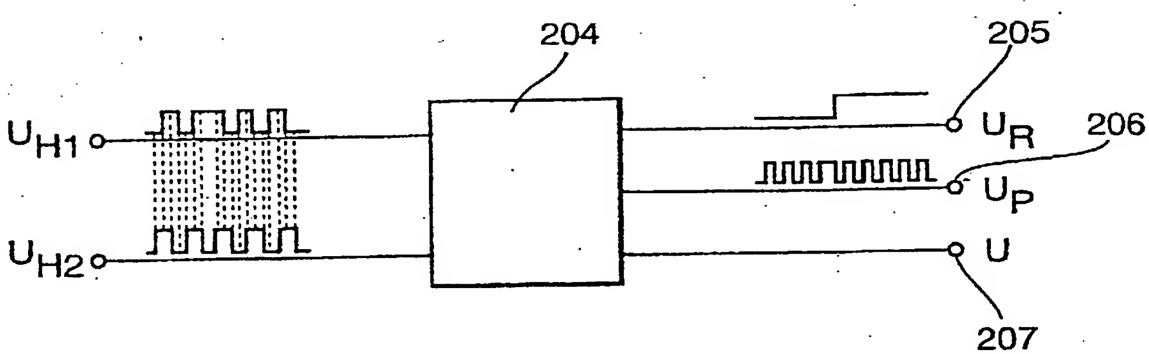

U_{H1}
t
U_{H2}
t
U_P
t

Fig. 8



U_{A1}
0
t
U_{A2}
0
a) Failure of one sensor
t
U_{A1}
0
t
U_{A2}
0
b) Failure of both sensors
t
U_{A1}
0
t
U_{A2}
0
c) Breakdown radiation (peaks)
t
U_{A1}
0
t
U_{A2}
0
d) Vibrations
t

Fig. 9



204
205
U_{H1}
U_{R}
206
U_{P}
U_{H2}
U
207

Fig. 10

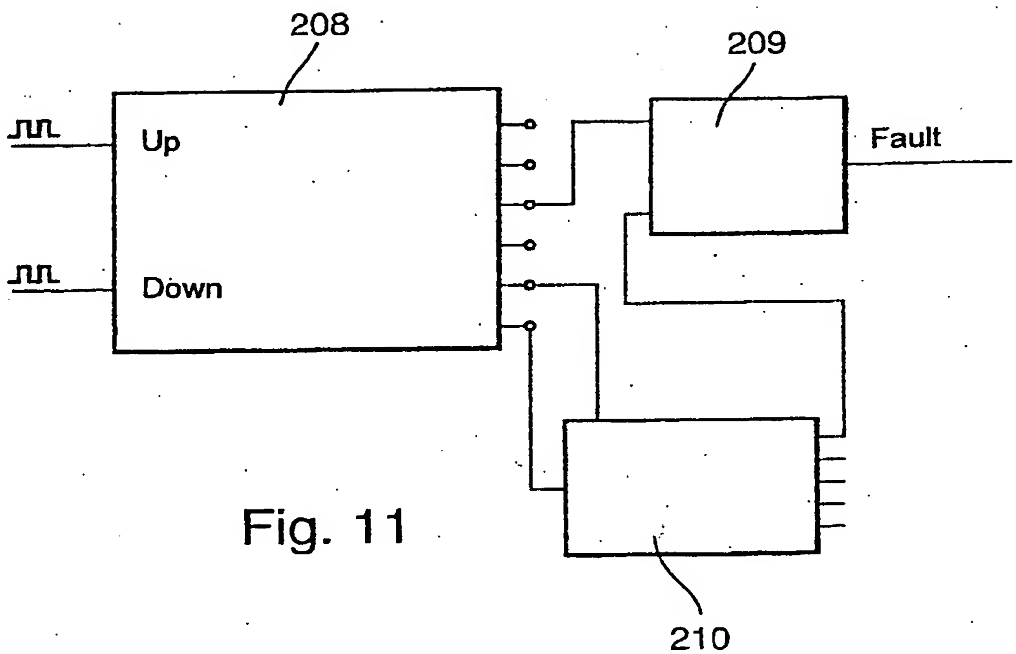
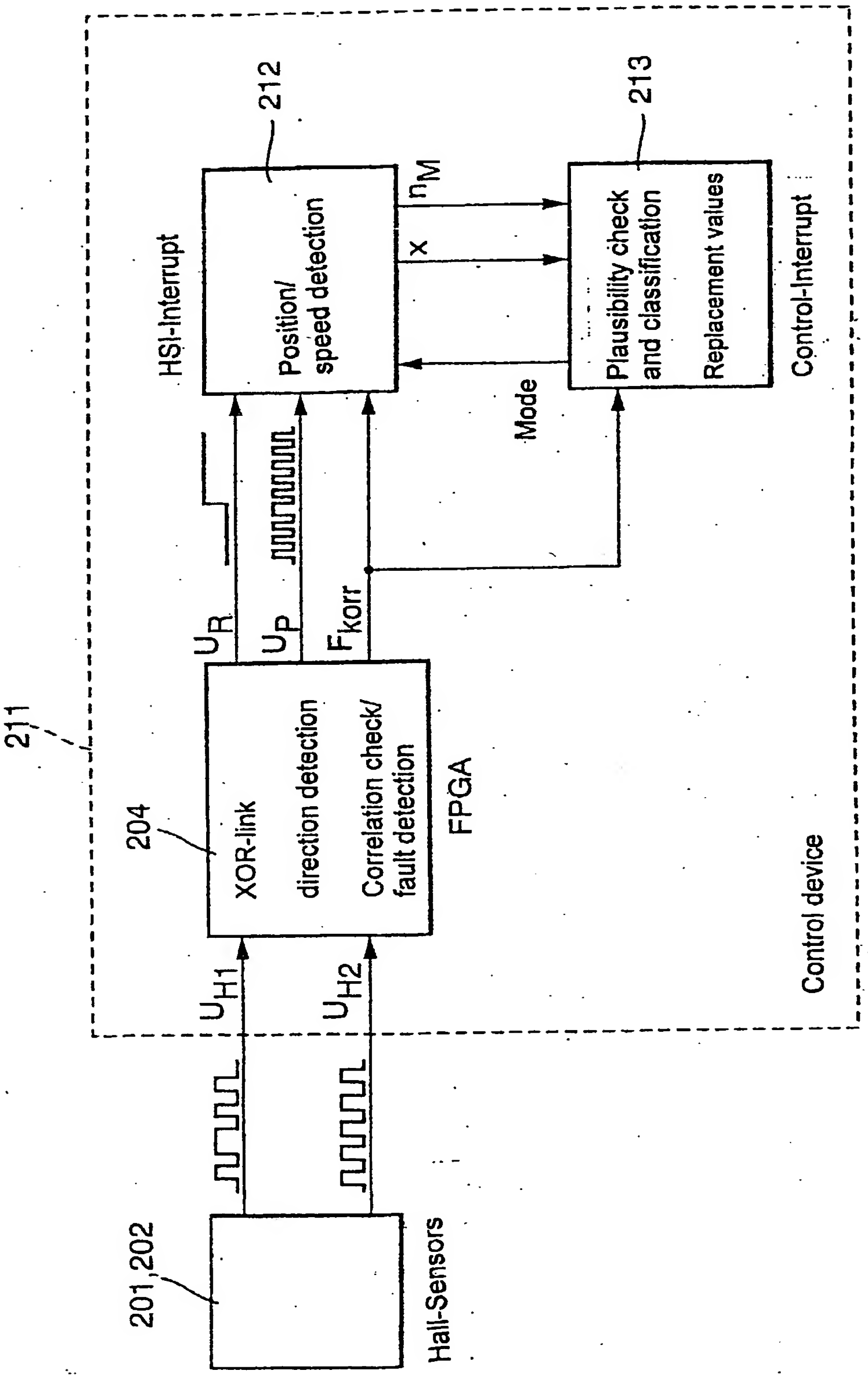


Fig. 11



Hall-Sensors
201,202
U_{H1}
U_{H2}
204
XOR-link
direction detection
Correlation check/
fault detection
FPGA
211
U_R
U_P
F_{korr}
HSI-Interrupt
Position/
speed detection
212
n_M
x
Mode
Plausibility check
and classification
Replacement values
213
Control-Interrupt
Control device

Fig. 12

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Method and device for controlling a clutch

The invention relates to a method and device for controlling a clutch, more particularly for the zero balance of a path measurement in the motion transfer from an actuator to a clutch, more particularly of a clutch contained in the drive train of a motor vehicle between a drive motor and a shift transmission.

The automation of clutches has become increasingly important in recent years. A considerable improvement in the driving comfort of motor vehicles can be achieved by automating clutches. At the same time savings in fuel are possible since owing to the simplified gear change driving is more frequently undertaken in the best possible gear. Furthermore automating a clutch is the prerequisite for automating the shift transmission which leads to automatic gearboxes which are more cost effective and thus operate with a better degree of efficiency than conventional automatic gears operating with planetary sets.

Automating a clutch by means of an actuator for example an electric motor requires accurate knowledge of the relevant operating position of the clutch. For this purpose a path measurement is undertaken in the motion transfer from the actuator to the clutch. This path measurement is naturally bound with tolerances which occur for example during operation of the clutch, or with immediate errors, such as may occur for example during the impulse counting of incremental sensors. It is therefore expedient to detect at least a predetermined operating position of the clutch and to evaluate this position as a reference value for the path measurement, i.e. to balance the path signal in the predetermined operating position for example to zero or another reference value.

From DE 44 33 825 A1 a clutch actuator is known having incremental path measurement wherein fixed stops at the two ends of the setting area of the clutch actuator serve as reference positions and thus for a possible counting error compensation.

Even if these end stops are accurately known the problem still remains that wear on the clutch, more particularly wear on the clutch lining, is not detected immediately which can lead to loss of comfort when operating the clutch. Similarly a for example temperature-conditioned change in the position of the plate spring tongues cannot be detected.

The object of the invention is to provide a method and device with which a precise detection of sensor errors which may possibly occur and thus an accurate positioning and/or speed measurement can be achieved.

According to a first aspect of the invention, there is provided a method for detecting and where applicable processing faults in the event of the incremental measuring of the position and/or speed of an element, more particularly an actuator in a motor vehicle wherein two sensors are arranged off-set along the path of movement of an element or a transmitter coupled therewith and in the event of movement of the element produce phase-offset impulse signal sequences which are evaluated through an evaluation circuit for detecting the position and/or speed which subjects the two impulse signal sequences to a correlation check and/or carries out a plausibility check with regard to the evaluation result.

According to a second aspect of the invention, there is provided a device for detecting and where applicable processing faults with the position and/or speed detection of an element, with an incremental measuring system with two sensors which produce phase-offset impulse signal sequences, and with an evaluation circuit which determines the position and/or speed of the element from the impulse signal sequences and has a correlation check stage for checking the correlation of the two impulse signal sequences and/or a plausibility check stage for checking the plausibility of the detected measured value through comparison with an estimated value formed for the measured parameters.

The invention also provides possibilities for processing such errors.

With incremental measuring systems, more particularly incremental path measuring systems the detection of sensor errors makes it possible to avoid an otherwise faulty position and/or speed determination. Particularly in the case of high precision systems such as for example with incremental path measuring systems on an electro-mechanical actuator of an electromotorized automated gearshift (ASG) it is possible to avoid a faulty positioning of this kind of a shift member which determines the gear selection.

With the fault detection according to the invention the impulse sequences produced by the sensors are subjected to a correlation check. Here the physically existing pulse sequences are checked to see whether they are similar.

With correct sensor signals the signals run substantially equal and are only subjected to short-term deviations with regard to their mutual phase position and their relevant impulse width in the event of a change in the direction of movement. Through this correlation check it is possible to achieve an exceptionally sharp evaluation of the correctness of the sensor signals.

As an alternative to the correlation check, but preferably in addition to same a plausibility check is carried out wherein an estimated value is formed for the parameter which is to be measured. This estimated value which roughly represents more or less the value which is actually to be anticipated is compared with the actual value. A judgement on the measured result is thus carried out using a reference value. In the event of greater deviations between the estimated value and the measured result this represents a clear reference to the existence of sensor errors.

Thus with the invention sensor errors can be established with high precision so that care can be taken to ensure that these faulty sensor signals do not lead to an undetected faulty determination of the position and/or speed of the setting element. The faulty sensor signals can then be replaced by replacement values obtained in a different way so that despite these sensor errors a sufficiently accurate position and speed determination is nevertheless still possible.

Advantageous developments of the invention are indicated in the sub-claims.

The invention can be used with all types of automatic clutch operation, even applications foreign to vehicles

and vehicle applications where the shift transmission is operated automatically by means of actuators.

The invention will now be explained below by way of example and with reference to the diagrammatic illustrations in which:

Figure 1	shows a drive train of a vehicle with automatic clutch;
Figure 2	shows a detail of the clutch operation according to Figure 1;
Figures 3 / 4	show two examples of characteristic lines of conventional clutches;
Figure 5	shows an engine characteristic field;
Figure 6	shows a flow chart for illustrating the bite point detection;
Figure 7	shows an embodiment of a transmitter for producing sensor signals;
Figure 8	shows the pulse signals sent by the transmitter according to Figure 7 as well as a pulse signal obtained by EXCLUSIVE-OR link of the two sensor signals;
Figure 9	shows different forms of sensor errors;
Figure 10	shows an example of a correlation test circuit;
Figure 11	shows a further embodiment of a correlation test circuit and
Figure 12	shows an embodiment with correlation and plausibility check.

According to Figure 1 a drive motor 2 of a motor vehicle is connected by an automatically operating clutch 4 to a gearbox 6 which through a Cardan shaft 8 drives a differential 10 of a rear axle 12 of the vehicle. In order to control the drive train an electronic control

device 14 is provided with input/output interfaces 16, a microprocessor 18 and a memory 20.

As sensors which supply the signals to the control device 14 are used a speed sensor 22, a torque sensor 24, an incremental sensor 26, a fresh charge through flow sensor 30, as well as a temperature sensor 32. The fresh charge through flow sensor detects the through flow of the fuel/air mixture for supplying the combustion engine.

In the drawing it is left open how the gearbox 6 is operated. If the gearbox 6 is operated automatically further sensors are provided in the gearbox. If it is operated manually additional sensors can be provided for the detection of the position of the gearbox and operation of a gear lever by a driver. A further input of the control device 14 is connected to an accelerator pedal 34. These signals can also be transferred by an engine control or another electronics unit through a data bus such as a CAN bus.

An actuator designed as an electric motor 36 for the clutch 4 and a throttle valve 38 of the drive motor 2 is controlled according to algorithms recorded in the control device 14 in dependence on the input signals supplied to same by the sensors. Another actuator for operating the torque engagement of the engine is also possible.

Figure 2 shows in slightly more detail an embodiment of a clutch controlled by an electric motor and which is operated automatically by an operating device and controlled by a control unit.

The electric motor 36 is housed inside a housing 40 and drives through a worm 42 connected rotationally secured to

its drive shaft a worm wheel 44 which is connected through a crank 46 to a linearly displaceable component part 48 which in turn is connected to the disengagement lever 50 of the clutch 4. The turning angle of the electric motor and/or worm 42 is detected by means of the incremental sensor 26 whose output lead 52 sends an impulse to the control device 14 when turning through each angular increment. Through the transmission ratio of the worm gear and the crank 46 a clear relationship exists between the increment count and the displacement of the component part 48 and thus through the given kinematics ratios the changes of the operating position of the clutch 4. An incremental path sensor can likewise be used as sensor to detect the engagement state of the clutch. This sensor can be between a disengagement system, such as a disengagement bearing, and the engine for driving the operating motion.

The control unit 14 makes a balance of the sensor at the existing bite point and stores this newly balanced sensor value in a memory of the control unit.

A stop pin 54 is provided on the worm wheel 44 and interacts with stops (not shown) fixed on the housing to restrict the rotation of the worm wheel 44 so that the clutch is operated each time inside the permitted displacement area. So that the electric motor 36 and the worm gear 42, 44 as well as the crank 46 are substantially relieved of the operating forces of the clutch a spring accumulator 56 interacts with the longitudinally movable component part 48.

Figure 3 shows the characteristic line of for example a so-called SAC clutch (self-adjusting clutch) as described in German Patent Application P 42 39 289.6. The torque M

transferable by the clutch is entered on the vertical and the operating path W on the horizontal. The shaded external surfaces indicate the setting area limits of corresponding stops in the actuator whereby the operating path W is for example the path of the linearly movable component part 48. As can be seen the clutch transfers the maximum torque in the rest position. In the rest position for example the stop pin 54 adjoins one of its stops or is slightly spaced from same. After a certain path of the component part 48 the contact pressure acting inside the clutch starts to decrease from position A and with further displacement of the component part 48 finally reaches the bite point G which is defined in that the clutch can transfer a predetermined torque Mg. With further activation the clutch comes out of engagement and can transfer no more torque so that the separating point T is reached. If the component part 48 is moved further then the point O of the complete opening of the clutch is finally reached.

The quality of the clutch control or regulation, i.e. the programmed comfort supplied to the driver depends quite decisively on the knowledge of the bite point G since the control-relevant standards such as e.g. distance a of the bite point from separating point, distance b of bite point from point A of the fully closed clutch and distance c between bite point and fully opened clutch are known in relation to the bite point. With the knowledge of this data it is possible to program algorithms which ensure comfortable coupling under all operating conditions. The said distances a, b, c are specific to the clutch and remain constant relative to the bite point G in the event of wear on the friction lining of the clutch. If the characteristic line of the clutch M (W) is recorded in a memory then with the knowledge of a point, such as for

example the bite point, it is possible to clearly define the characteristic line.

An accurate knowledge of the absolute position of the bite point G for example through a certain counter state of the counter associated with the incremental sensor 26 in the control device 14 is thus a decisive pre-requisite for a more reliable and well-defined operation of the automatic clutch operation. How this bite point setting of the component part 48 can be used as reference value for the path measurement such as incremental path measurement through the incremental sensor 40 and can be constantly up-dated will be explained below in further detail.

Figure 4 shows an illustration corresponding to Figure 3 for a clutch which is depressed. The reference numerals correspond functionally to those of Figure 3 wherein the point A of the maximum torque to be transferred used in practice during driving operation naturally has a slight distance from the absolute setting area limits (shaded on the right).

The relative position between the shaded setting area limits and the bite point G changes with wear, thermal expansion or centrifugal force of the clutch lining so that the boundaries are advantageously detected directly by means of the stop pin 54 or after an initial fixing in the new state of the clutch are calculated from the relevant displacement of the bite point G or are recognised in another way. The recognition of a setting area boundary leads to the switching off of the actuator so that thus is protected from overload and the clutch is safeguarded against damage.

A bite point detection with balance of the path measurement is explained by way of example from Figures 5 and 6.

Figure 5 shows an engine characteristic field. The load throughput Ø measured by the through-flow sensor 30 is shown on the vertical. The horizontal indicates the speed n detected by the speed sensor 28. The cluster of curves diagrammatically indicate for different operating temperatures T1 to T5 of the drive motor the relationship between the speed and load through-flow whereby the curves are each determined at a predetermined load torque, i.e. at the bite point of the clutch. Figure 5 thus represents a "bite point torque characteristic field" of the drive motor 2 with the clutch 4.

It may now be assumed according to Figure 6 that the clutch 4 is fully opened in the event of a starting off process, i.e. it is located at point 0 and a gear is engaged and in stage 100 the command of "close clutch" is issued by the control device 20 whereupon the electric motor 36 starts to run and the component part 48 is moved in the closing direction of the clutch 4. In stage 102 it is constantly determined whether one of the characteristic field points according to Figure 5 is reached, i.e. whether with relevant operation of the accelerator pedal 34, or relevant through flow F and relevant engine temperature T the engine speed corresponds to a value stored in the characteristic field according to Figure 5. If this is the case, then this is evaluated as reaching the bite point G and the counter state reached in the control device 14 of a counter associated with the incremental sensor 26 is stored as the up-dated reference value in the memory 20. At the same time in stage 106 a clutch operating program is activated which happens each

time on reaching the bite point G and a comfortable operation of the clutch is guaranteed corresponding to the relevant demands (position of the accelerator pedal 34).

In a similar way the reference value can be balanced each time when the bite point G is reached so that the path measurement is each time set to a defined reference value and the operating state of the clutch can be controlled or regulated with precision from the path measurement.

It is obvious that there are numerous other possibilities for determining the bite point, for example in that the

torque sensor 24 reaches a certain torque which is naturally dependent on the switched gear, or in that a support torque is measured which the drive motor 2 exerts on its bearing etc.

In order to explain the present invention first it is necessary to explain using Figures 7 to 9 the sensor section of an incremental path measuring system including the output signals issued by same.

Figure 7 shows a diagrammatic illustration of the sensor section of the incremental path measuring system with a control magnet 201 which has a number of magnetic pole teeth and is attached to the output shaft of an electric motor (not shown) or is coupled to same so that rotation of the output shaft causes rotation of the control magnet 201. The electric motor forms the actuator of an automated gearbox and serves for the linear adjustment of a shift member which produces the setting of the gearbox and which is to be displaced according to the gear selection ordered by the driver of the vehicle. Two or more sensors, preferably in the form of echo sensors 202 and 203 are mounted on the circumferential track of the control magnet 201 and on passing by the magnetic poles each produce output signals U_{H1} and U_{H2}. As a result of the off-set arrangement of the sensors 202 and 203 the pulse signals U_{H1} and U_{H2} produced by same are phase-staggered as shown in Figure 8.

From the relevant phase position of the two impulse sequences U_{H1} and U_{H2} it is possible to determine the rotary direction of the control magnet 201 and thus of the electric motor driving same and consequently the position and/or speed of the element to be controlled. According

to the detected direction of rotation the pulses (increments) are added up with correct signs to produce the relevant position of the element which is to be monitored or controlled. Furthermore the frequency of the pulse signal which is in clear relationship with the speed of the electric motor or with the speed of the element (setting member) driven by same is produced from the number of the impulses per unit time or by detecting the impulse period length with the aid of a reference counter.

In order to increase the position resolution the two pulse sequences U_{H1} and U_{H2} can be subjected to an EXCLUSIVE-OR link so that the pulse signal U_P shown at the bottom in Figure 8 is produced which contains doubled frequency as the pulse signals U_{H1} and U_{H2} and thus twice as many flank transitions. The position resolution can be doubled with an evaluation of the pulse signal U_P.

For another doubling of the resolution it is furthermore possible to provide a twin-flank evaluation wherein the working of an interrupt routine for position detection with each positive and negative flank of the pulse signal UP is called up.

An additional reference position measurement is preferably provided through which the absolute reference can again be produced since only relative path changes can be detected with incremental path measuring systems.

First the most important fault possibilities will be described with reference to Figure 9 in the case of incremental path measuring using echo sensors.

In all Figures 9a) to 9d) the relevant upper impulse outline represents the output signal of the one echo sensor whilst the signal path indicated underneath represents the output signal of the other sensor.

Figure 9a shows the case of a complete breakdown of one of the two echo sensors 202, 203 which has the result that just only one of the two echo sensors produces an impulse signal whilst the signal of the other echo sensor constantly has the value 0 or 1.

Figure 9b shows the case of the breakdown of both echo sensors 202, 203. In this case both sensors supply constant output level to both signal leads which can either both lie at 0 or have a value deviating from 0.

In Figure 9c the case is shown where additional breakdown impulses are superimposed which can be produced for example through electromagnetic radiation. These breakdown impulses (peaks) can simulate additional sensor impulses or can also completely or partially cancel sensor impulses. These breakdown impulses can in principle not be differentiated from the genuine sensor impulses. Since the effect of these breakdown impulses on the two echo sensors are however generally as a result of their local stagger of different strength the sensor signals are also clearly influenced to different degrees. The upper curve outline in Figure 9c shows that the output signal of the one echo sensor is substantially undisturbed whilst the lower curve outline in Figure 9c shows that the sensor signal illustrated there is severely distorted by the breakdown impulse.

Figure 9d shows the case of vibrations of the control magnet 201 and thus of the element to be monitored or the

electromechanical actuator about a rest position. Vibrations of this kind can lead to the one sensor signal (upper curve outline) showing a pulse sequence with a pulse frequency dependent on the vibrations whilst the output signal of the other sensor has a constant level. With this motion development a constantly changing motion direction is produced so that an alternating direction signal is to be produced which causes a correct sign summation of the increments or impulses and thus the correct position value is achieved. The signal pattern which may be adjusted where applicable in the event of vibrations is thus similar to that in the case of a sensor failure (Figure 9a). However the signal pattern in the event of renewed governing of the drive, i.e. preferably of the electromechanical drive, changes over to the normal signal pattern since now both sensors again produce pulse sequences.

Prior to the actual signal evaluation processing takes place of the pulse signals sent by the sensors 202, 203. The pulse signals are hereby close-tolerance filtered to suppress high-frequency interferences caused by electromagnetic radiations and, as known in the prior art, 'bounced out'. An upper boundary frequency is hereby fixed for the pulse sequence. As an alternative it is also possible to define a minimum permissible pulse duration and not to evaluate pulses with shorter pulse duration. Temporary interference radiations between individual impulses or in the area of the rising or falling impulse flanks are hereby reliably suppressed. This pre-processing can be carried out by means of separate elements or in the input circuitry of the signal evaluation stage. In many cases this pre-processing can also be omitted.

The pulse signals, pre-processed where applicable, are then subjected to a processing to detect sensor errors. This processing contains a correlation check and/or a plausibility check. The correlation check will first be described below in greater detail.

The correlation check is a logical processing wherein deviations of the two pulse signal sequences are recognised and signalled to the superposed control. This signalling of established inadmissible deviations is important particularly in the case of an EXCLUSIVE-OR link of the two sensor signals for doubling the pulse frequency since with the failure of a sensor signal the pulse frequency of the output signal formed by the EXCLUSIVE-OR link is halved and this halving must be taken into account and compensated when detecting the position and speed, particularly within the scope of the interrupt service routine for detecting the position.

The correlation check is based on the fact that the two impulse sequences U_{H1} and U_{H2} normally run substantially synchronously and do not noticeably differ with regard to the impulse count per unit time at least with a constant rotary direction. With the correlation check it is checked whether the two pulse sequences U_{H1} and U_{H2} run asynchronously, i.e. they differ with regard to their impulse count by more than a predetermined threshold n1 which can be adjusted where applicable. If it is established that the pulse sequences differ substantially by more than n1 alternate impulses, a fault signal is produced, i.e. a fault recognition is set.

Figure 10 shows an embodiment of the correlation check wherein the two pulse signals U_{H1} and U_{H2} are supplied to a

correlation test circuit 204 in the form of a freely programmable logic circuit FPGA (field programmable gate array). The logic circuit 204 carries out the EXCLUSIVE-OR link of the input signals and hereby forms the pulse signal U_P sent to an output connection 206. Furthermore the logic circuit 204 implements the detection of a change of rotary direction from a displacement of the mutual phase positions of the input pulse signals and produces at an output connection 205 the rotary direction signal U_R which can only assume two levels corresponding to the relevant rotary direction.

Furthermore the logic circuit 204 carries out the correlation check and sends in dependence on the test result at the output connection 207 a signal U_{Fehler} whose level is switched over with the detection of inadmissible deviations signalling sensor errors and signals the presence of errors to the superposed control. If it is then established that the sensor signals have again reached the correlated state the error signal is set back. This signal evaluation can be effected by counting routines in the logic circuit 204, i.e. through corresponding programming. By way of example the lacking correlation of the two pulse sequences U_{H1} and U_{H2} on the input side can take place by means of a two-directional counting function which forms a pulse difference counter and with each rising (or dropping) flank of the one pulse signal counts up and with each rising (or dropping) flank of the other signal counts down. If the counting state of the two-directional counting function exceeds or understeps a certain threshold value then the fault detection is set. The threshold value can be preset fixed or can be adjustable.

The correlation check is also continued after establishing the fault detection. If it is hereby detected that the pulse sequences have again passed into the correlated state the fault detection is automatically reversed. This reversal can then take place for example if a defined number n_2 of impulses of the two pulse sequences following each other in system-correct alternation has been detected. The number n_2 can hereby be equal to n_1 or can differ from same. The check on re-establishing the correlation can be carried out for example by means of a counter or counting function which thus forms a correlation counter and counts the number of correctly alternating sequential impulses of the two pulse sequences. The correlation counter is then moved back each time when two or more successive impulses are present in the same signal without intermediate appearance of an impulse in the other signal. If the counting state of the correlation counter exceeds the threshold value n_2 the fault detection is reversed.

With the design according to Figure 10 the logic for this correlation check of the two input signals is implemented in terms of hardware within the scope of the logic circuit 204, i.e. the input circuit for the control apparatus on the output side connected to the output connections 205 to 207. The control device is hereby not loaded through this correlation check. It is however also possible to undertake the correlation check within the control device. In this case the output 207 can be omitted in the case of the logic circuit 204.

Figure 11 shows details of an embodiment of the correlation check circuit with automatic reversal of the fault signal on re-establishing the correlated state. A

two-direction counter 208 receives at its upward counting input "UP" the one impulse signal, for example U_{H1} whilst the other pulse signal, for example U_{H2} is sent to its downward counting input "DOWN". With correlated impulse sequences the impulses appear alternately so that the counting value of the two-directional counter 208 changes constantly between 0 and 1, i.e. only the lowest value Bit LSB of the counter output switches over alternately. All higher-value bit steps of the counter output permanently maintain the lower level state. With the appearance of a fault, for example the failure of the pulse signal adjoining the downward counting input, the two-directional counter 208 counts up so that the higher value output bit steps change one after the other to the high level. The setting input of a flip-flop 209 is connected with a higher-value bit connection, for example the bit step number 204, so that this is set to +/- 8 when the counter 8 is counting up and produces the fault signal at its output.

For the automatic resetting of the fault detection after re-establishing the correlation a further counter 210 is provided whose counting input is connected to the bit step LSB of the two-directional counter 208. The counter 210 therefore counts the number of successive signal changes at the output LSB. The cancelling input CL of the counter 210 is connected to the output bit 202 of the two-directional counter 208 so that the counter 210 is then cancelled each time when the output bit 202 of the two-directional counter 208 changes from 0 to 1. If no correlation exists the signal level of the output bit 202 of the two-directional counter 208 changes repeatedly between 0 and 1 so that the counter 210 is moved back again and again. Only when the correlation of the two

input pulse signals is reached again does just only the output bit 1 (LSB) repeatedly change its level so that the counter 210 counts up and is not cancelled again. The resetting input of the flip-flop 209 is connected with a higher-value output bit, for example the output bit 205 of the counter output 210 so that the flip-flop 209 is again moved back and thus the fault signal is set at 0 when a certain number of alternate impulses of the input pulse sequence has been detected.

With the circuit according to Figure 11 the case can occur where despite correctly re-established correlation the outputs of the counter 208 connected to the setting input of the flip-flop 209 or to the cancelling connection of the counter 210 permanently retain the value "1". Therefore flank-triggered inputs for the setting input and cancelling connection are preferably used which only respond to rising flanks and not however to a continuously applied signal. Alternatively the two-directional counter 208 can be periodically moved back.

The plausibility check will be explained in greater detail in the following. Here an estimated value is formed from other measured values for the parameters to be measured and this estimated value is compared with the measured value. If the deviations lie within a specific permissible scope then it can be assumed from this that the measured value is correct, i.e. the sensor signals are undisturbed, and thus the measured value can be judged as reliable. This procedure can be used for any parameters which are to be measured, for example position, speed or revs. An example will be explained below in further detail wherein a motor is used as the electromechanical actuator whose speed is to be determined from the sensor

signals. This speed at the same time represents the clear statement on the relevant speed, and thus also the relevant location of the element driven by the motor.

In order to form the estimated value the engine speed can be calculated approximately as follows by disregarding the armature time constants with the current build-up from the armature voltage U_A of the armature current I_A as well as known engine characteristic values:

$$n_M = \frac{1}{2\pi} \frac{U_A - R_A I_A}{k\Phi}$$

Here R_A designates the armature resistance (including all the parasitic resistances such as the shunt resistances for measuring current, inner resistance of the end stage and voltage supply etc). k designates the engine constants, whilst F designates the magnetic flux caused by the permanent magnet 201.

As a result of disregarding the armature time constants and also owing to the temperature influences and other parameter fluctuations such as ageing-conditioned changes with this procedure only one estimated value is produced for the actual engine speed which is however nevertheless relatively accurate and can be used for the plausibility check on the measured value.

As an alternative to the direct calculation of the estimated value for the speed or also as an addition thereto the speed can be detected by means of a fault observer which is needle-matched through the armature

current. To this end for example an actuator model (fault value observer) is reproduced which is needle-matched through the armature current. The estimated value for the fault size, i.e. for the engine speed is obtained as the starting value for the observer.

The armature current which is to be measured for determining the estimated speed value can be measured for amount and direction at any point. Preferably, for a cost-effective technically simple implementation, the armature current is measured in the mass path of the power end stage wherein the armature current can only have one current direction. The armature current need thus only be detected with regards to amount which can be undertaken in a technical simple manner.

The correlation and plausibility check are preferably carried out combined so that the sensor faults explained at the beginning are reliably detected and furthermore can also be treated accordingly. Replacement strategies can thus be prepared for recognised sensor faults.

The following Table 1 provides an overview of the classification of sensor faults and the replacement strategies to be used in the event of a fault.

		Correlation check	
		Signals OK	Signals faulty
Plausibility check	Signals OK	Sensor signal OK ¶ direction signal ü ¶ pulse signal ü	'Vibration' or breakdown impulse superimposed on one side ¶ direction signal ü ¶ pulse signal ü
	Signals faulty	Systematic faults in both sensor signals ¶ Determine position through integration of estimated speed value	Breakdown of sensor ¶ direction signal from estimated speed value ¶ pulse signal with half pulse frequency

As can be seen from Table 1 the direction signal and pulse signal are adopted unchanged when the plausibility check has shown that the sensor signals are substantially correct. This applies both for the case where the correlation check has found no fault and for the case where the correlation check has detected the signals as faulty. In this case the signal breakdowns are classified as vibrations or interference impulses superimposed on one side.

If the plausibility check has however led to the result “signals faulty”, with a correctly passed correlation check it is concluded there are systematic errors in the two sensor signals and as a reaction the position of the element driven by the drive device is determined through integration of the estimated speed value. If the correlation check ought also to have led to the result “signals faulty” in this case it is concluded that the

sensor has broken down and the direction signal is formed from the estimated speed value and with the position and/or speed evaluation it is taken into account that the pulse signal has only half the pulse frequency.

With the plausibility check a fault tolerance is hereby provided, i.e. a permissible difference is allowed between the estimated value and the actual measured value. Only if the deviation between the estimated value and the actual measured value is greater than this fault tolerance is the plausibility check evaluated as not passed and faulty sensor signals are concluded.

The plausibility check and the preparation where required of suitable replacement values for measured values detected as faulty can be undertaken both in a high speed interrupt or high speed interrupt routine (HIS-Interrupt = high speed input interrupt) which is triggered in the event of each positive and/or negative signal flank of the input signal adjoining same. As an alternative it is also possible to undertake this plausibility check and/or the where applicable required preparation of suitable replacement values in a "low-frequency" operating control interrupt or control interrupt routine which is provided for example for the position regulation. In order to avoid too strong a load on the processor the plausibility check and the replacement value preparation are preferably provided in the control interrupt.

Figure 12 shows an embodiment where a control device 211 not only contains the logic circuit 204 but also a high speed input interrupt (interrupt routine or section) 212 (HSI-interrupt) and a control interrupt routine 213 (control interrupt). The high speed input interrupt 212

receives the three output signals U_R, U_P and $F_{korr}(=U_{Fehler})$ of the logic circuit 204 and causes the position and speed detection. The fault signal sent by the logic circuit 4 is also applied to the control interrupt 213 which carries out the plausibility check and classification and dependent on the detected fault states and the state of the fault signal of the logic circuit 204 prepares replacement values (Table 1). The control-interrupt receives for the plausibility check from the high speed input interrupt 212 the speed value n_M and the position signal x and compares these values with the estimated value formed internally.

The control interrupt 213 is furthermore connected to the high speed input interrupt 212 through a signal line "Mode" through which in the event of detecting the breakdown of a sensor this state is signalled to the high speed input interrupt 212. Particularly in the case of the EXCLUSIVE-OR link of the two pulse signals U_{H1} and U_{H2} and the frequency doubling hereby obtained the signal "Mode" signals in the event of a detected breakdown of a sensor that the pulse signal U_P applied to the high speed input interrupt still only has half frequency and therefore an evaluation is to be made still only in consideration of this halved frequency.

As an alternative the position and speed detection can also be carried out in the control interrupt 213. In this case only one direction-dependent counter for adding up the increments and determining the time duration between two pulse flanks (counter state) runs in the high speed input interrupt 212. The evaluation of these values takes place in the control interrupt 213 taking into account the quality, that is the freedom from faults or affliction

with faults, of the sensor signals. With this embodiment the load on the processor of the control device is reduced as a result of the simplified service routine of the high speed input interrupt.

The present invention cannot only be used with electromechanical actuators in automated gearboxes but can be used quite generally with any type of control devices and sensor configurations wherein a parameter of any kind is to be determined by evaluating two or more pulse-like phase-offset sensor signals. The incremental measuring process and measuring apparatus are however preferably an incremental path measuring process and incremental path measuring system.

The invention is not restricted to the embodiments of the description. Numerous amendments and modifications are possible within the scope of the claims, particularly those variations, elements and combinations and/or materials which result from combinations or modifications of individual features or elements or process steps contained in the drawings and described in connection with the general description and embodiments and claims.

Claims

1. Method for detecting and where applicable processing faults in the event of the incremental measuring of the position and/or speed of an element, more particularly an actuator in a motor vehicle wherein two sensors are arranged off-set along the path of movement of an element or a transmitter coupled therewith and in the event of movement of the element the sensors produce phase-offset impulse signal sequences which are evaluated through an evaluation circuit for detecting the position and/or speed which subjects the two impulse signal sequences to a correlation check and/or carries out a plausibility check with regard to the evaluation result.

2. Method as claimed in Claim 1, wherein the evaluation circuit with the correlation check determines mutual deviations of the two impulse signal sequences and when detecting deviations exceeding a threshold value produces a fault signal.

3. Method as claimed in Claim 1 or Claim 2, wherein the evaluation circuit determines differences in the impulse number of the two impulse signal sequences and with a difference exceeding a threshold value produces a fault signal.

4. Method as claimed in any preceding claim, wherein the evaluation circuit contains a two-directional counter which counts the impulses of the one impulse signal sequence in the upward direction and those of the other

impulse signal sequence in the downward direction and on reaching or exceeding or understepping a certain counting value produces a fault signal.

5. Method as claimed in any preceding claim, wherein the evaluation circuit continues the correlation check even after detection of a fault and reverses a fault signal signalling the missing correlation when the correlation is given again for a certain duration or a certain impulse count.

6. Method as claimed in Claim 5, with a counter which counts in dependence on the number of uninterrupted sequential impulse changes between the two impulse signal sequences and on reaching a certain count level causes the reversal of the fault signal.

7. Method as claimed in any preceding claim, wherein the evaluation circuit has an input circuit, more particularly in the form of a freely programmable logic circuit adjoined by the two impulse signal sequences and carrying out the correlation check.

8. Method as claimed in Claim 7, wherein the freely programmable logic circuit produces a pulse output signal (U_P) formed in particular through EXCLUSIVE-OR link of the two impulse signal sequences, and a rotary direction signal (U_R) as well as preferably where applicable also a fault signal (U_{Fehler}) in the event of a lack of correlation.

9. Method as claimed in any preceding claim, wherein for the plausibility check an estimated value is formed for the parameter to be determined and this is compared with the measured value determined by the evaluation circuit for this parameter.

10. Method as claimed in Claim 9, wherein the estimated value is formed from the speed of a motor driving the element.

11. Method as claimed in Claim 10, wherein the engine speed of the engine is estimated from the armature voltage and armature current of the motor.

12. Method as claimed in any preceding claim, with a breakdown value observe which detects a drive parameter, more particularly the armature current and forms the estimated value from this.

13. Method as claimed in any preceding claim, wherein the armature current of the motor is measured as the end phase producing the armature current, more particularly in the mass path.

14. Method as claimed in any preceding claim, wherein the plausibility check and preferably also the position and/or speed detection, more particularly the speed detection, is carried out in an interrupt-control of a control device.

15. Method as claimed in Claim 14, wherein the interrupt control contains a high speed input interrupt control

which is activated with each positive and/or negative signal flank.

16. Method as claimed in Claim 14 or Claim 15, wherein the interrupt control is an interrupt control, more particularly for the position regulation of the actuator.

17. Method as claimed in any preceding claim, wherein the sensors are echo sensors.

18. Method as claimed in any preceding claim, wherein the two impulse signal sequences are subjected to an EXCLUSIVE-OR link to form a pulse signal of doubled frequency.

19. Method as claimed in any preceding claim, wherein then if the plausibility check signals faulty signals the correlation check produces no fault notification and the position of the element is determined by integration of the estimated value, more particularly the engine speed estimated value.

20. Method as claimed in any preceding claim, wherein then if both the plausibility check and the correlation check indicate faulty signals the direction signal for the direction of movement of the element is determined from the estimated value, more particularly the engine speed estimated value.

21. Method as claimed in Claim 20, wherein a signal is supplied to an evaluation stage producing the position and/or speed detection which signals that the pulse sequence formed by the EXCLUSIVE OR link of the two impulse signal sequences has only half pulse frequency.

22. Device for detecting and where applicable processing faults with the position and/or speed detection of an element, with an incremental measuring system with two sensors which produce phase-offset impulse signal sequences, and with an evaluation circuit which determines the position and/or speed of the element from the impulse signal sequences and has a correlation check stage for checking the correlation of the two impulse signal sequences and/or a plausibility check stage for checking the plausibility of the detected measured value through comparison with an estimated value formed for the measured parameters.

23. Device as claimed in Claim 22, wherein the correlation check stage and/or plausibility check stage are contained in one control device connected to the sensors.

24. Device as claimed in Claim 22 or Claim 23, wherein the correlation check stage is contained in an input circuit, more particularly in a freely programmable logic circuit.

25. Device as claimed in Claim 22 or Claim 23, wherein a two-direction counter is provided to which are supplied the one impulse signal sequence at the upward counting connection and the other impulse signal sequence at the downward counting connection.

26. Device as claimed in Claim 25, with a further counter which counts the number of proper impulse changes between the two impulse signal sequences and causes the reversal of a fault signal signalling a lack of correlation on reaching a certain counting value.

27. Device as claimed in any one of Claims 22 to 24, with a high speed input interrupt control which carries out the position and/or speed detection more particularly the speed detection.

28. Device as claimed in any one of Claims 22 to 27, with an interrupt control for the position regulation which forms the plausibility check stage.

29. Device as claimed in Claim 27 or Claim 28, wherein the interrupt control of the high speed input interrupt control supplies a characterisation signal ("Mode") when the plausibility check has not been passed.

30. Device as claimed in any one of Claims 22 to 29, wherein the plausibility check stage when the plausibility check has not been passed prepares replacement values for the or each parameter which is to be measured.

31. Device as claimed in any one of Claims 22 to 30, wherein the evaluation circuit is a control device more particularly for controlling an automatic gearbox.

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Application No:	GB 0204538.3	**Examiner:**	Jason Clee
Claims searched:	1 to 31	**Date of search:**	4 April 2002

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Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): F2L: LC & LE

Int Cl (Ed.7): F16D 28/00
G01D 5/244

Other: Online: WPI, EPODOC & JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	EP 0575663 A	(VDO Schindling) especially see column 1 lines 1 to 23, column 5 line 13 to line 22, and the figure	1, 7, & 22-24
X	US 4430647	(Robert Bosch GmbH) especially see the abstract and figures 1 to 4	1 & 22

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